Quantitative Determination of the Rate of Hydrogen-Ion Heating by an Argon-Ion Beam

Michael O. Chandler/ES83
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The Argon Release for Controlled Studies sounding rocket was launched from the Poker Flat Research Range on February 23, 1990, carrying a complement of scientific instruments designed to study the near-Earth plasma environment. Among the instruments in the payload was the superthermal ion-mass spectrometer, which was designed and built by MSFC. One of the goals of this flight was to study the interaction of an artificially produced argon-ion beam with the naturally occurring plasma. Argon-ion beams of 100 to 200 electron volts were ejected from a daughter payload, while the naturally occurring ions were observed on the main payload using the superthermal spectrometer. The interaction of the beam and the background plasma generated plasma waves (specifically lower hybrid waves), which, in turn, preferentially heated the ambient hydrogen ions. A previously published study[1] showed that the heating was also restricted to directions perpendicular to the magnetic field, resulting in hydrogen ions that possessed distinctly different characteristic temperatures when viewed in directions parallel and perpendicular to the magnetic field.

A further investigation of these data was initiated in an effort to determine the local heating rate for the hydrogen ions as a result of the beam-plasma interaction. The approach was to model the natural cooling of hydrogen ions to the background-neutral atmosphere and assume that these two species were in local thermodynamic equilibrium, i.e., that their total cooling rate was equal to their total heating rate. Thus, calculating the total cooling rate from the model also provided the total heating rate. For the beam-heated hydrogen ions (i.e., the ones observed perpendicular to the magnetic field), the total heating was a combination of the beam heating and any naturally occurring ion heating that was present. Given this, the temperature observed in the direction parallel to the magnetic field was assumed to provide a measure of the undisturbed plasma—the hydrogen ions unaffected by the argon-ion beam. Therefore, the normal daytime heating of the ions which took place in the absence of any beams could be equated to the total cooling rate of the parallel ions. Finally, the heating due to the beam-plasma interaction was taken to be equivalent to the total cooling rate of the perpendicular ions (equal to their total heating rate) less the total cooling rate of the parallel ions (equal to the normal daytime heating rate).

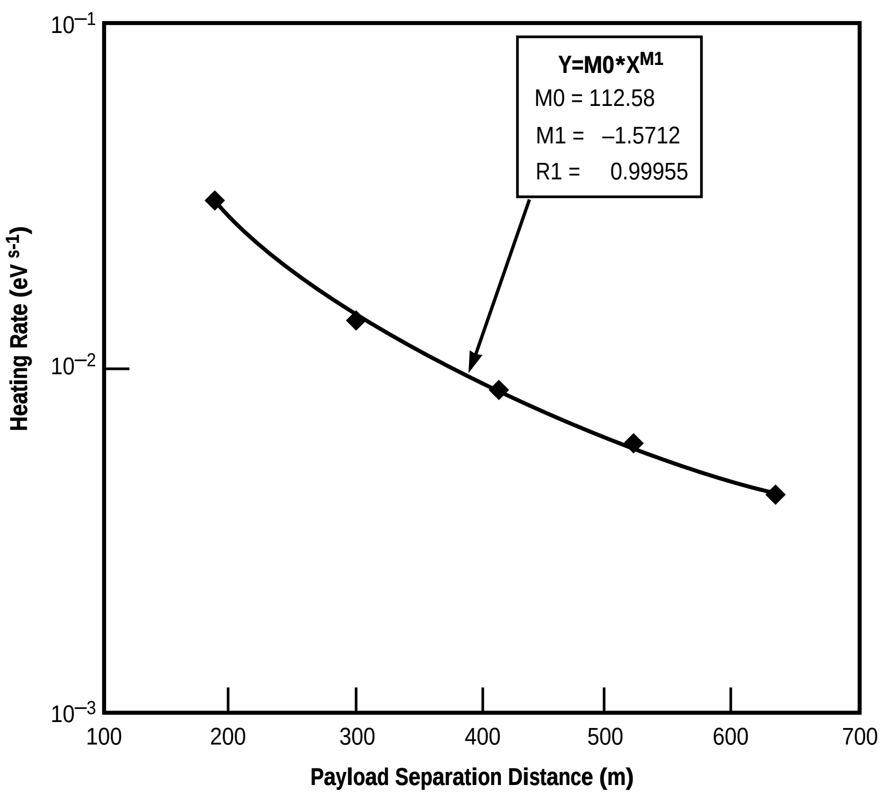

FIGURE 29.—The beam heating rate/ion as a function of the distance between the payloads.

The findings of this study not only give a quantitative measure of the beam heating, but also show the variation of this heating with the changing distance between the mother and daughter payloads (i.e., between the beam origin and the superthermal ion-mass spectrometer). Figure 29 illustrates this variation and includes an approximation to the data in the form of a power-law function. The result is that for the Argon Release Controlled Studies sounding rocket geometry, the rate of ambient ion-beam heating decreased as the 3/2 power of the separation distance. This fact can now be applied to the observed wave data and to plasma theory to determine the mechanism for transfer of energy from the beam to the hydrogen ions. Similar heating is observed to occur naturally in regions of the near-Earth plasma environment and upper atmosphere near the latitudes associated with the aurora.

Pollock, C.J.; Chandler, M.O.; Moore, T.E.; Arnoldy, R.L.; Kintner, P.M.; Chesney, S.; and Cahill, L.J., Jr. 1995. Preferential Heating of Light Ions During an Ionospheric Argon Ion Injection Experiment. *Journal of Geophysical Research*, 100:14, 557.

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